

Final Report

Fulton, MO Veterans Park Project

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Table of Contents

Introduction	3
Overview of Levee	3
Objective	3
Site-specific Challenges	3
Limited access	3
Susceptible Vegetation	4
Flooding Cadence	5
Approach	5
Long-term vs. short-term solutions	6
Comprehensive Methods	6
Proposed Suite of Solutions	7
Regrading	7
Rock Toe	7
Mats	8
Check Dams	8
Vegetation Management -Tree Removal Strategies Mariam	8
Long Term Plan for Replanting Trees/Vegetation	8
Accessibility	9
Recommendations	9
Table 1: Instructions, equipment and cost to install jute mats.	12
Rock Toe Overview	12
Table 2: Costs to purchase, transport, and install riprap	13
Regrading Overview	14
Check Dams Overview	21
Maintenance Strategies for Vegetation/Slope/Rock toe- Mariam (long term plants)	23
Table 5: Cost Analysis Summary of Short and Long Term Erosion Control Methods	23
Table A1. Supply companies and contact information	25

Introduction

A man-made levee in Fulton, Missouri's Veteran's Park protects the park and its surrounding area from flooding and helps to control water flow within the region. However, damages from past overtopping and increasingly common flashy flooding have made the levee vulnerable to failure. This project's primary focus is to provide recommendations for strengthening the levee.

Overview of Levee

The levee consists of a hillside that separates a lake from Smith Branch with a small gravel walkway. An outfall pipe has alleviated the stress of water seepage from the lake on the eroding slope. However, the hillside's inability to retain soil has led to exposed roots and undercutting above the flowline. These factors have contributed to an inconsistent and dangerously steep slope that ultimately threatens release of the lake into the creek. The following recommendations aim to provide lasting stability to the area so it can be enjoyed for many years to come.

Objective

The primary aim of this report is to summarize potential cost-effective solutions to create a more resilient levee for Veterans Park. Our team has researched relevant short-term recommendations that can be expanded upon into the future to create more permanent levee stability while still temporarily increasing the structural integrity of the levee to withstand severe precipitation events.

Site-specific Challenges

Limited access

The project site is located in the middle of the park, on the southwest side of the park's lake. Access to the levee on the east side is limited because of its relatively narrow crest (~10 ft wide), high height (~12 ft above flowline during dry season), and steep slope. Further, the

washout, the most erosion affected area of the levee, has begun to stretch into the crest of the levee, making this section of the levee particularly weak. Access from the west side is also limited because Smith Branch separates the east of the park from the west side, where the levee is located. Two roads run through the park: Helen Stephens Lane and Richard Ault Drive. Helen Stephens Lane runs parallel to Smith Branch on the west side of the levee. Though, no road leads directly to Smith Branch from either side of the levee. Therefore, construction on the levee should be approached from the west side of Smith Branch.



Figure 1: Satellite Map of Veterans Park

Susceptible Vegetation

The majority of the small and large ash trees (*Fraxinus*) and shrubs trees that line Stinson Creek bed have shown signs of emerald ash borer (*Agrilus planipennis*) infestation, which are responsible for millions of dead ash trees in the United States. Seven out of the eight large ash trees whose roots are currently holding the soil in place have blanding markings and d-shaped holes, which have resulted in the ash borer eggs burrowing under the bark and consuming the

stems that bring water and sugar to a vitalized and healthy tree. Usually ash borer infestations may take two to three years to show in a newly infected tree.¹

Flooding Cadence

Per the 2022 Missouri Climate Summaries from NOAA's National Center For Environmental Information, Missouri has seen an increase in the frequency of extreme precipitation events over the last few decades.² Further, the state's topographical position at the intersection of several lower river basins means downstream flooding is an extreme hazard across the state. Historical data suggests that more extreme flooding events occur between March through September.³

Approach

Over the course of four months, we employed a multi-pronged approach to both finding and evaluating the solutions that would be the best fit for the levee in Veteran's Park. To begin, we identified the landscape of potential solutions through web-based exploration, which allowed us to become familiar with the most effective slope stabilization products on the market. We also reviewed case studies on flooding and the strategies employed within areas similar to Fulton. Throughout this process, we interviewed Sarah Phipps from the Missouri Department of Agriculture, Forest Entomologist Robbie Doerhoff, State Entomologist Collin Wamsley, and Andrew Lane, Cheadle Center for Biodiversity & Ecological Restoration Coordinator. These interviews allowed us to gain insight on the multiple dimensions of the problem and viability of solutions. We held several remote meetings with Fulton City engineers to learn about the history of the erosion within the area and the goals for the City of Fulton.

Once we developed an understanding of the problem and potential solutions, we visited Fulton in person to take measurements of the levee slope, capture photos of levee features, see

¹ "Emerald Ash Borer - The Arbor Day Foundation."

<https://www.arborday.org/trees/health/pests/emerald-ash-borer.cfm>. Accessed 27 Feb. 2023.

² "Missouri - State Climate Summaries 2022." <https://statesummaries.ncics.org/chapter/mo/>. Accessed 4 Feb. 2023.

³ "Climate in Four Seasons - Missouri - Weather Spark."

<https://weatherspark.com/y/10942/Average-Weather-in-Four-Seasons-Missouri-United-States-Year-Round>. Accessed 9 Feb. 2023.

effective solutions in neighboring areas with similar levee issues, further develop our relationship with Fulton City engineers, and get to know Fulton community dynamics. Overall this trip gave us a more accurate understanding of the complex issue at hand. In sharing recommendations our goal is to provide Fulton with increased resilience to flash floods and other extreme weather events.

When evaluating which levee restoration strategies that would be appropriate for the levee in Veteran's Park, we prioritized long term solutions that encourage both current stabilization as well as future soil retention and plant growth. Because of the park's significance to the community, we considered local aesthetics, such as maintaining tree cover and protecting the lake, were considered throughout the research process.

Long-term vs. short-term solutions

The immediate goal is to minimize the likelihood of continued erosion from the most vulnerable section of the levee, the washout. By prioritizing the stabilization of the most first, the immediate threat of a levee failure will be less likely.

Comprehensive Methods

To create a resilient solution for the levee in Veterans Park, we recommend a suite of manufactured and nature based solutions that will work in concert with one another to increase the resilience of the levee in Veterans Park. We are using this approach because the solutions we outline in this report have varying timelines before they can start to effectively slow down the erosion of the embankment. For example, planting native trees and grasses will root in roughly 3-6 weeks and help to hold the freshly placed topsoil in place through precipitation.⁴ To further fortify the newly placed topsoil, laying erosion control blankets will over the most vulnerable area of the levee. New trees can also be planted alongside native wildflowers and grasses once the slope has been regraded but are a long-term solution that will support the structural integrity

⁴ "Big Bluestem Drought Tolerant Native Prairie Grass or Ornamental" <https://www.outsidepride.com/seed/native-grass-seed/bluestem-big-native-grass-seed.html>. Accessed 28 Feb. 2023.

over time in six months to a year once the transplanted tree roots have established.⁵ Additionally, nature-based solutions, like established vegetation, are more cost-effective than manufactured solutions, like polypropylene erosion control blankets.

Proposed Suite of Solutions

Regrading

Regrading can help strengthen the washout area within the critical region in order to keep the tree roots in place and build resiliency within the crumbling soil. The process of regrading will benefit the eroded area by providing a strong and consistent surface to grow vegetation. Regrading has actively worked in creating a buffer zone for flattened landscapes against harsh water intensive systems, which will work well to mitigate erosion impacts such as rainwater runoff and soil permeability.

Rock Toe

We recommend using riprap to create a stabilizing rocktoe which will hold soil in place and prevent further erosion. Using revetments like riprap is considered by the Army Cor Of Engineers to be a traditional long-term stream embankment restoration approach.⁶ Riprap is a permanent layer of large, angular stones meant to armor and stabilize shore banks.⁷ The goal of riprap is to serve as a revetment that can absorb some of the incoming energy from water traveling down the branch during an extreme precipitation event. Because this project deals with a steep slope and requires both short and long term stability, Riprap is uniquely applicable because it can provide a solid foundation for regrading the slope and starts doing its job the day it is installed unlike other long-term solutions like establishing vegetation.

⁵ "Establishment period for trees - Environmental Horticulture." <https://hort.ifas.ufl.edu/woody/establishment-period.shtml>. Accessed 28 Feb. 2023.

⁶ "Innovative Methods for Levee Rehabilitation - DTIC." <https://apps.dtic.mil/sti/pdfs/ADA354949.pdf>. Accessed 4 Feb. 2023.

⁷ "Riprap Erosion Control - Wisconsin DNR." <https://dnr.wisconsin.gov/topic/Waterways/shoreline/erosioncontrol-riprap.html>. Accessed 19 Feb. 2023.

The installation of a rock toe can armor shorelines and create lasting protection against the scouring of the waterline during intense rainfall⁸. This man-made structure mimics natural structural reinforcement of banks and can prevent future soil loss. In combination with other soil retention practices, the rock toe serves as a permanent solution to the flooding issue at hand. Add language about riprap

Mats

Jute mats can hold newly introduced soil in place and act as a protective barrier to floods while new vegetation grows. Because these mats are biodegradable and do not need to be removed, they add to the soil and reduce the labor cost over time. Another benefit to these mats is that they can be placed between trees so that less vegetation has to be removed in the installation process⁹.

Check Dams

During extreme weather events when the likelihood of flash floods increases, the flow rate of Smith Branch will increase considerably. An increase in flow rate increases the likelihood of erosion, posing threats to the foundation of embankments along rivers and streams.¹⁰ Check dams are often wooden or rock based structures placed in the stream that function as a source of resistance against erosion, therefore slowing the flow rate of the stream in specific sections and increasing sediment storage. Research has shown that the presence of check dams are effective in lowering the peak discharge rate downstream and also improving ecological functions of the stream.¹¹¹²

⁸ "Engineering With Nature | FEMA." https://www.fema.gov/pdf/about/regions/regionx/Engineering_With_Nature_Web.pdf. Accessed 19 Feb. 2023.

⁹ "Steep Slope Stabilization - Safe Harbor." <https://www.safeharborenv.com/steep-slope-very-steep-slope-and-coastal-bluff-stabilization-1>. Accessed 19 Feb. 2023.

¹⁰ "(PDF) Erosion due to high flow velocities: A description of relevant" https://www.researchgate.net/publication/49115738_Erosion_due_to_high_flow_velocities_A_description_of_relevant_processes. Accessed 22 Feb. 2023.

¹¹ "Effects of a check dam system on the runoff generation and" <https://www.sciencedirect.com/science/article/pii/S2095633921000678>. Accessed 23 Feb. 2023.

¹² "Flow, turbulence, and drag associated with engineered log jams in a" 1 Nov. 2015, <https://www.sciencedirect.com/science/article/pii/S0169555X15301100>. Accessed 23 Feb. 2023.

Long Term Plan for Replanting Trees/Vegetation

The aim of the tree removal strategy is to create a clear open landscape to create a durable structure after regrading has occurred and the jute mats are placed on top. Leaving the two tree roots within the highly vulnerable zone in place is vital to soil retention, and the large eight the infected ash trees within the 50 foot vulnerable zone must be cut at the base or treated to prevent the risk of falling trees, which can pose a hazard to people and infrastructure as ash trees quickly decay and lose structural integrity.¹³ A secondary benefit, is it may be helpful to reduce emerald ash borer (EAB) infestation within the ash trees in the area. The viability of the trees needs to be inspected by an arborist to see which are heavily infected with EAB. With the dead trees removed the chance of continued infection can reduce, especially if the remaining trees in place have been treated.

Once regrading has been completed, the planting of various wildflowers, juvenile dogwood trees and shrubs can benefit the longevity of soil resistance as the root system establishes. Planting certain species of grasses and shrubs is important because variations of root length from the fauna can strengthen soil retention, and limit crumbling from erosion. This crumble overtime would make the creek wider and the streamflow can carry away the tree roots in place.

Accessibility

The washout area, which will also be referred to as the most vulnerable area of the levee in this report, extends roughly 11 feet across the middle of the levee. This washout area has significant indentations, an uneven slope gradient, and visibly exposed tree roots. Ideally, an excavator would be used on the crest of the levee to regrade the areas where the washout is most severe. However, because of the instability of the washout area, we are uncertain if the levee could reliably support even the lightest excavators that weigh around 6,000 lbs. While there is no road that leads directly to Smith Branch from either side of the levee, the west side of Helen Stephens Lane offers a much more favorable slope for transporting soil and riprap. A relatively

¹³ "Ash regeneration capacity after emerald ash borer (EAB) outbreaks."
<https://familyforests.org/wp-content/uploads/2019/07/Ash-regeneration-capacity-36233.pdf>. Accessed 27 Feb. 2023.

small excavator could potentially be used here to dig a trench for riprap, lay the riprap, regrade the levee slope, and pack the soil.

Recommendations

Biodegradable Mat Overview

Jute mats are an economical, environmentally-safe, and forward-thinking erosion prevention solution that could help reinforce the Veteran's Park levee. Because the levee wall is steep, freshly planted vegetation is susceptible to erosion, so jute mats help ensure the successful growth of stabilizing vegetation. It is a priority to leave existing healthy vegetation in place and introduce new vegetation to the levee base and sides to reinforce the integrity of the levee and reduce unnecessary soil loss. The jute mats can easily be cut to navigate around existing vegetation, thus allowing healthy trees to remain on the hillside. Newer vegetation will also benefit from the jute mats holding the soil in place, so that roots can establish within the soil. Because past levee erosion caused significant topsoil depletion, maintaining adequate moisture and nutrients are important to support both existing and newly established vegetation. Jute mats can retain more than 400% of their weight in moisture for the vegetation and introduce minerals such as calcium and iron into the soil as the natural material slowly breaks down¹⁴. Jute mats are also biodegradable, so no clean up efforts are needed and wildlife will not be threatened by harmful microplastics¹⁵.

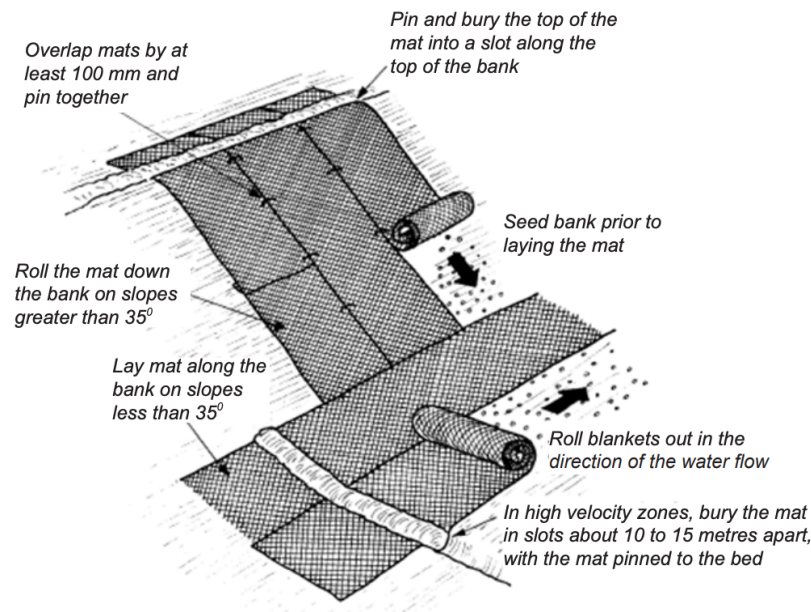
Time of year, amount of time, range of expense, specialized labor needs

Because the jute mats are placed to promote vegetation growth, the mat timeline should correlate with the introduction of new seeds. Because it would be best to plant vegetation in March, laying the mats in April will allow the seeds to become established and grow. The application of the mats themselves is a simple process that includes digging an anchor along the

¹⁴ "Jute Matting Effectively Controls Soil Erosion - NYP Corp.." <https://nyp-corp.com/blog/jute-matting-effectively-controls-erosion/index.html>. Accessed 8 Feb. 2023.

¹⁵ "(PDF) Integrated Nutrient Management in Jute Crop: A Review." 15 Jul. 2022, https://www.researchgate.net/publication/362013974_Integrated_Nutrient_Management_in_Jute_Crop_A_Review. Accessed 19 Feb. 2023.

top of the levee, securing the mat within the anchor and covering the top portion with soil, and rolling the jute mat down the hillside.¹⁶ Mats will have to be pre cut to allow space for the trees.¹⁷



Source: WRC (2001a)

Figure 8 Orientation of matting on slopes and channels

Figure 2: Diagram depicting erosion mat installation process

Equipment and Accessibility Needs

The cost to cover the slope along the 50 foot area of severe vulnerability with jute mats would be around \$300 for the mats themselves and another \$120 for the steel pins needed to secure the mats every 1.5 feet¹⁸.

¹⁶ "Installation of Erosion Mat on Slopes - La Crosse County."

https://lacrossecounty.org/docs/default-source/land-conservation/erosion-mat-installation-on-slopes.pdf?sfvrsn=76c41398_2. Accessed 19 Feb. 2023.

¹⁷ "1 EROSION CONTROL MATTING - Parks and Wildlife Service."

<https://www.dpaw.wa.gov.au/images/documents/conservation-management/riverpark/Management/Best%20management%20practices%20for%20foreshore%20stabilisation%20-%20Erosion%20control%20mattng.pdf>. Accessed 19 Feb. 2023.

¹⁸ "Jute Mat Erosion Control Blanket, 4' x 225' | Forestry Suppliers, Inc.."

<https://www.forestry-suppliers.com/p/43439/40641/jute-mat-erosion-control-blanket-4-225>. Accessed 9 Feb. 2023.

A tackling gun will be necessary to place the steel pins along the jute mats to secure them in place. These can be rented for \$195 a week, which should provide enough time to install the mats¹⁹. A trench digger is also important to create the anchor along the levee. Hand digging the trench along the newly graded soil will save the cost of an excavator, especially since an effective anchor only needs to be 6 inches deep.

Table 1: Instructions, equipment and cost to install jute mats.

		Equipment needed	Cost
Procure jute mats	Purchase 500 ft ² of jute mats to cover the entirety of the levee	500 square footage of jute mats	Approx. \$300
Secure jute mats	Place steel pins 1.5 feet apart along the edges of the jute mats with a tackling gun	1 Tackling gun (rented)	\$195/week*
		330 Steel pins	Approx. \$120
Create anchor for mats along the top of the levee	Dig a 6-inch trench along the newly graded soil	10-Gauge Excavator/ Track Shovel	Approx. \$100

**One week should provide enough time to secure jute mats in place*

Examples of Other Places That Implemented This Solution

The company Safe Harbors has utilized natural systems to stabilize steep slopes and eroding coastal bluffs in Massachusetts with jute mats²⁰. The mats were able to be placed around

¹⁹ "Equipment Rental, Hydroseeder for Rent - Hydroseed Supply." <https://hydroseedsupply.com/equipment-rental>. Accessed 9 Feb. 2023.

²⁰ "Steep Slope Stabilization - Safe Harbor." <https://www.safeharborenv.com/steep-slope-very-steep-slope-and-coastal-bluff-stabilization-1>. Accessed 19 Feb. 2023.

existing trees, and cultivate new vegetation to the area by securing and adding nutrients to the topsoil.

Rock Toe Overview

The rock toe will be made up of 3-6 inch riprap stacked on top of each other. A one-foot deep trench will need to be dug along the stream bank where the levee is adjacent to Stinson Creek to stabilize the rocks and provide a solid foundation. Within the trench, a thin layer of gravel must be placed to ensure the soil beneath does not shift²¹. The 3-6 inch rip rap will then be placed in the trenches, extending three feet high above surface level with a slope of 1:1.

Table 2: Costs to purchase, transport, and install riprap

	Action Items	Equipment needed	Cost
Procure riprap	Purchase ~75 tons of 3-6 inch rip rap from Con-Agg Companies	n/a	~ \$1538.25 for 75 tons
Deliver riprap to the site	Con-Agg offers delivery services and can transport 75 tons 3-6 inch riprap in 3-4 truck loads (per Con-Agg estimate) ²²	n/a	~ (\$125 per load + 15% (<i>variable</i>) fuel surcharge) x 4 loads = \$575 for delivery
Install riprap in toe trench and scale up levee wall	Dig 1 foot rock toe along the 50 ft. most vulnerable area of the	Mini-excavator rental to maneuver riprap	~ \$340 daily or \$845 weekly ²³

²¹ "Resloping, Rock Toe and Riprap - Vermont.gov." https://dec.vermont.gov/sites/dec/files/wsm/lakes/Lakewise/docs/LP_BMPReslopingRockToeRiprap.pdf. Accessed 9 Feb. 2023.

²² "Contact | Con Agg Companies." <https://www.conagg-mo.com/contact/>. Accessed 21 Feb. 2023.

²³ "Rent Heavy Equipment with T3 Technology | EquipmentShare." <https://rent-now.estrack.com/#/home/rental/earthmoving/mini-excavators/class/42>. Accessed 21 Feb. 2023.

	levee		
Total Costs	Riprap Procurement + Delivery + Installation	n/a	~ \$2000 - \$2500

The rock toe will be built during early September to allow for a mild climate so that installation will be less likely to be halted by weather. The 50 foot section just beneath the past overtopping damage requires the most immediate attention, but ideally the entire stream bank lining the levee would receive a rock toe border on either side of the stream. The rock toe would extend 410 feet on either side of the levee and extend 3 feet high with a slope of 1:1.

Examples of Other Places That Implemented This Solution

Rock toes have been used in conjunction with erosion control mats to slow harmful erosion permanently. FEMA has reported riprap’s ability to provide protection against areas that are constantly worn away by repetitive hydrological activity²⁴. While riprap provides lasting protection, it is also important to use natural solutions as well so that the riparian area is still available as habitat and ecosystem services such as filtration.

Regrading Overview

Before regrading the washout area, it is critical that all debris is removed from the washout area so that the loam soil can fully fill the depression and allow the water to compact. To do so efficiently, we recommend using an excavator to take away all detritus in the embankment cavity. In doing so, some soil will be excavated and should be inspected to ensure it is free of debris before being used as backfill when reconstructing the slope. Before applying new topsoil, the slope should undergo a manual process called core aeration to loosen the existing soil to a depth of about one foot before laying new topsoil to ensure a healthy growth

²⁴ "Engineering With Nature | FEMA." https://www.fema.gov/pdf/about/regions/regionx/Engineering_With_Nature_Web.pdf. Accessed 9 Feb. 2023.

medium for vegetation.²⁵ Then, the freshly placed topsoil should be excavated either by an excavator. This process can also be done by using hand-held tools but will take considerably longer. Therefore, we recommend clearing debris and regrading the levee embankment in the drier months from October to February with an excavator so as to minimize the risk of precipitation delaying the progress of the project.²⁶

Equipment and Accessibility Needs

A small excavator should enter from the west side to fill the washout area of the levee with new topsoil when the stream gage height is low. After, the excavator should dig a 1 foot trench and move the riprap to fill in the newly made trench. Silt loam and riprap will have to be filled in the washout area and toe trench, respectively.

Vegetation/Tree Removal Overview

The vegetation and tree removal solution on our list is to remove infested trees and establish certain species of shrubs and trees along the creek bed and edges of the creek. The combination of planting both are important to plant because variations of root length from shrubs and grasses can strengthen soil retention, and limit crumbling, which is what is currently happening with the trees in place now. This crumble overtime would make the creek wider and the streamflow can carry away the tree roots in place without the methods recommended above. The plant species recommended are able to withstand full sun and shaded environments that the canopy tree cover will provide. The plants also have high water retention rates that will be able to withstand flooding levels during the wet season. These species are summer and cool perennial plants that can bloom during the different seasons.

Removal of approximately seventy to hundred small trees that have a diameter less than twenty inches is recommended for the jute matts to rest upon. For the eight large trees with clear EAB infestation signs should be removed at the base, with the tree roots left in place to keep the

²⁵ "Water Runs Downhill: Managing Runoff on Steep Slopes."
https://www.stcplanning.org/wp-content/uploads/2021/07/WaterRunsDownhill_Guidance.pdf. Accessed 23 Feb. 2023.

²⁶ "Climate in Four Seasons - Missouri - Weather Spark."
<https://weatherspark.com/y/10942/Average-Weather-in-Four-Seasons-Missouri-United-States-Year-Round>. Accessed 9 Feb. 2023.

soil intact. The infected ash trees should be inspected for broken branches, large d-shaped hallows, fungal infection, s-shaped tunnels where the larvae consume under the bark, blanding marks created from feeding woodpeckers, and sparse leaf coverage during the ash tree's blooming season. Below is a chart of what these symptoms look like.²⁷

*It is important to note, that when transporting dead ash tree logs as a result of an emerald ash borer infestation that they do not contain live larvae or borer as the pest can cause damage to trees outside of their infecting zone that may not have had infection before.²⁸

Signs & Symptoms of EAB

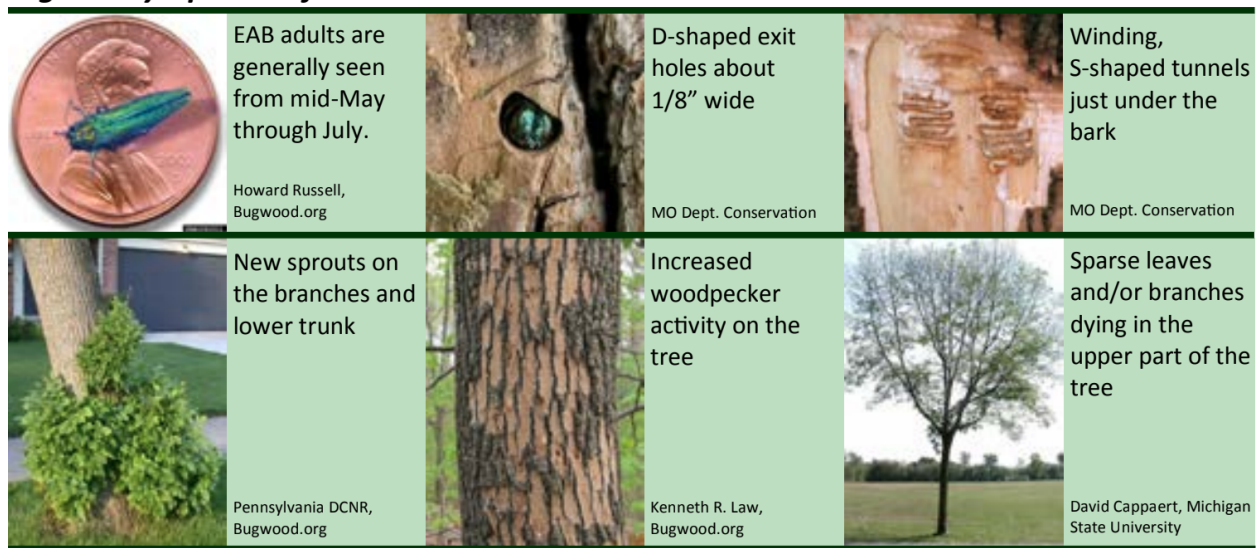


Figure 3: Signs of EAB infestation, produced by the Missouri Department of Conservation (<https://mdc.mo.gov/>)

²⁷ "Ash regeneration capacity after emerald ash borer (EAB) outbreaks." <https://familyforests.org/wp-content/uploads/2019/07/Ash-regeneration-capacity-36233.pdf>. Accessed 27 Feb. 2023.

²⁸ "INSECT HOT TOPICS: Emerald ash borer on the move." https://ucnfanews.ucanr.edu/Articles/Insect_Hot_Topics/INSECT_HOT_TOPICS_Emerald_ash_borer_on_the_move/. Accessed 27 Feb. 2023.

Table 3: Tree Removal Cost Estimate

Tree Removal Cost (Size)	Cost x Number of Trees	Total Cost Estimate
Big Trees (20+ inches in diameter)	\$600 - \$1200 x 8 large trees	\$4,000 - \$9,600
Small Trees (20- inches in diameter)	\$150 - \$700 x 70 to 100 small trees	\$10,500 - \$15,200

Vegetation Addition:

After the jute mats have been established over the soil, the addition of developed alternate-leaved dogwood and red mulberry trees, and various local native perennials can be planted within the soil. The plantation of big bluestem, river oats, tall coreopsis, culver root, sampson snake root, and indian grass can create a complex root system that will promote soil resiliency. These plants have been chosen with the site specific challenges that have been observed. These species are capable of growing within shaded and full sun atmospheric conditions, and have high water retention capacity which can last within heavily wet environments for varying lengths of time which will be explained in the table below.

Care Instructions:

- To prepare the site the existing vegetation seedlings need to be removed so they do not interfere with the growth process of the new plant species.
- Once planted, check the site every two weeks to observe seed head emergence.
- Scattering seeds needs to be implemented before the first or after the last frost of the winter season so the seedlings stay viable.

- Weeds and unwanted vegetation have a significant impact as they strengthen the soil. The tedious weed that has caused problems in central Missouri is hucklesuckle which needs to be constantly removed.²⁹
- Test the drainage of the soil as trees need to be well-drained in order to grow successfully.

Time of Year, Amount of Time, Range of Expense, Specialized Labor Needs

Pagoda Dogwood: If chosen to transplant this tree, it should be removed during the dry season and planted during dormancy in late fall or early spring. It doesn't require much maintenance other than providing fertile soil and a wide circle of mulch surrounding the tree to retain soil moisture.³⁰ If chosen to propagate the tree, pagoda dogwood is best propagated by cutting 6-inches from the tip of a branch and rooting them in the soil, with at least four to six leaves on the stem. To properly ensure growth under the soil, remove two leaves from the side of the branch you intend to root into the dirt. Next, acquire a small pot of moistened rooting medium and dip the bottom of the stem about 1 ½ inches and cover the stem tightly with the rooting medium. After that wrap a large plastic bag around the pot making sure it is sealed and the leaves are not touching the plastic. Check the stem once a week to observe any root development which you can see from the bottom of the pot or tugging at the stem. Finally, once the root has established, move the tree into a large pot with potting soil and establish onto the landscape.³¹

If choosing to grow Pagoda dogwood from seed, collect the seeds and sow them ¼ or ½ inches in a prepared outdoor bed in the soil. Take the time to ensure that the location receives partial shade during summer. Next after mulching and marking the location solidify the temperature of the seed to have two to three months of cold stratification³² at 40 degrees Fahrenheit immediately followed by seventy to eighty degrees Fahrenheit for which the seeds can germinate. Once they do emerge in spring, water them within the absence of rain and clear the bed of weeds. Common

²⁹ "How to Grow Dogwoods From Seeds - Home Guides."

<https://homeguides.sfgate.com/grow-dogwoods-seeds-45104.html>. Accessed 28 Feb. 2023.

³⁰ "How to Grow and Care for Pagoda Dogwood - The Spruce." 21 Sep. 2022, <https://www.thespruce.com/golden-shadows-pagoda-dogwood-2132847>. Accessed 28 Feb. 2023.

³¹ "How to Grow and Care for Pagoda Dogwood - The Spruce." 21 Sep. 2022, <https://www.thespruce.com/golden-shadows-pagoda-dogwood-2132847>. Accessed 28 Feb. 2023.

³² "What Does It Mean to Stratify or Scarify Seeds? - The Spruce." 17 Aug. 2021, <https://www.thespruce.com/stratification-seeds-into-thinking-its-winter-1403100>. Accessed 28 Feb. 2023.

Pests and Disease are leaf spotting, twig and leaf blight, root rot and canker, and occasional insects like scale, borers and leaf miner.³³

Red Mulberry: Propagating a mulberry tree can be done by branch cutting an 8 in long piece that is ½ in diameter. Then placing the branch 3 inches under root medium filled with soil and potting mix. After this, water thoroughly and place the pot in a plastic bag in a shaded environment for 4 weeks. Once the plant has rooted, remove the plastic bag and continue to grow the plant till it can become planted on site in fall.³⁴ Common pests can be deer as they browse through the shrubs, but a simple fence can hold them off.

Big Bluestem: Propagating big bluestem can be completed through division using a very sharp object. Start this process in early spring once the plant is matured and has come out of dormancy.³⁵

River Oats: Propagating river oats can be completed through division, which should be transplanted between spring and early summer.³⁶

- Maintenance Strategies for Vegetation/Slope

To regularly monitor the slope condition to ensure the solution is effective at stabilizing the soil, there should be a waiting period for a full year cycle to establish vegetation growth, the vegetation should be prospering during its blooming season. If the trees are transplanted on site, the root connectivity will establish within a 3-6 month range, but if the tree grows as a seedling the root propagation will sprout up to 12-30 inches in the first year and take 5-7 years to bloom if not more.

Table 4: Tree and Vegetation Addition Cost Estimates

³³ "How to Grow and Care for Pagoda Dogwood - The Spruce." 21 Sep. 2022, <https://www.thespruce.com/golden-shadows-pagoda-dogwood-2132847>. Accessed 28 Feb. 2023.

³⁴ "How to Grow and Care for Red Mulberry - The Spruce." 27 Sep. 2022, <https://www.thespruce.com/growing-red-mulberry-trees-5101681>. Accessed 28 Feb. 2023.

³⁵ "Big Bluestem: Plant Care & Growing Guide - The Spruce." 15 Oct. 2021, <https://www.thespruce.com/big-bluestem-plant-profile-4845878>. Accessed 28 Feb. 2023.

³⁶ "How to Grow and Care for Northern Sea Oats - The Spruce." 29 Apr. 2022, <https://www.thespruce.com/northern-sea-oats-growing-guide-5224490>. Accessed 28 Feb. 2023.

Species	Propagation	Growth Time + Conditions	Expense
Alternate-leaved dogwood Trees (<i>C. alternifolia</i>) ³⁷ Common Name: <i>Pagoda Dogwood</i>	Plant: During dormancy early Spring to late Fall ³⁸ Blooms: July - September	Time: Slow to moderate, about 20 ft in 25 years. Conditions: Full sun exposure, loamy well drained soil, acidic soil PH ³⁹	Price Range: \$100-\$220 ⁴⁰ Or \$30 per gallon tub ⁴¹
Red Mulberry (<i>morus rubra</i>) ⁴²	Plant: Early Spring to late Fall Blooms: March to April	Time: 2 to 2.5 feet/year and lives about 75 to 125 years ⁴³ Conditions: Partial to full sun exposure, moist and well drained soil, neutral to basic soil PH ⁴⁴	\$110 per tree in a 5 gallon pot ⁴⁵
Big BlueStem (<i>Andropogon</i>	Plant: Seeds planted in Early Spring or	Time: Up to 7ft, but by the second or third year it should	\$6.50 per quart pot ⁴⁸⁴⁹

³⁷ "Dogwoods - Missouri Department of Conservation."

<https://mdc.mo.gov/discover-nature/field-guide/dogwoods>. Accessed 22 Feb. 2023.

³⁸ "How to Grow and Care for Pagoda Dogwood - The Spruce." 21 Sep. 2022,

<https://www.thespruce.com/golden-shadows-pagoda-dogwood-2132847>. Accessed 23 Feb. 2023.

³⁹ "How to Grow and Care for Pagoda Dogwood - The Spruce." 21 Sep. 2022,

<https://www.thespruce.com/golden-shadows-pagoda-dogwood-2132847>. Accessed 23 Feb. 2023.

⁴⁰ "Dogwood Trees For Sale | The Tree Center."

<https://www.thetreecenter.com/flowering-trees/dogwood-trees/>. Accessed 23 Feb. 2023.

⁴¹ "Pagoda Dogwood - Cornus alternifolia - Prairie Nursery."

<https://www.prairienursery.com/pagoda-dogwood-cornus-alternifolia.html>. Accessed 26 Feb. 2023.

⁴² "Red Mulberry | Missouri Department of Conservation."

<https://mdc.mo.gov/discover-nature/field-guide/red-mulberry>. Accessed 23 Feb. 2023.

⁴³ "Red Mulberry Tree Morus rubra - Dave's Garden." <https://davesgarden.com/guides/pf/go/58163/>. Accessed 27 Feb. 2023.

⁴⁴ "Red Mulberry | Missouri Department of Conservation."

<https://mdc.mo.gov/discover-nature/field-guide/red-mulberry>. Accessed 23 Feb. 2023.

⁴⁵ "Red Mulberry Tree (Morus rubra) - 3 Gallon Pot - Wilson Bros Gardens."

<https://www.wilsonbrosgardens.com/red-mulberry-tree-3-gallon.html>. Accessed 23 Feb. 2023.

⁴⁸ "Big Bluestem (Andropogon gerardii) - Missouri Wildflowers Nursery."

https://mowildflowers-net.3dcartstores.com/Big-Bluestem-Andropogon-gerardii_p_41.html. Accessed 23 Feb. 2023.

⁴⁹ "Red Mulberry Tree Morus rubra - Dave's Garden." <https://davesgarden.com/guides/pf/go/58163/>. Accessed 27 Feb. 2023.

<i>gerardi</i>), a cool season grass.	Late Winter ⁴⁶ Blooms: Summer	be topping 8-10' ⁴⁷ Conditions: Full sun and part shade, loamy and well drained soil.	
River Oats (<i>Chasmanthium latifolium</i>), a cool season grass. Common Name: Northern Sea Oats, Indian Wood Oats, Inland Sea Oats ⁵⁰	Plant: Propagate through division and transplant it anytime between mid-Spring and early Summer. Blooms: Late Summer	Time: 2-5 ft depending on the amount of sun received ⁵¹ Conditions: Full sun and part shade, loamy and well drained soil. ⁵²	\$6.50 per quart pot ⁵³
Total			\$3,854

Emerald Ash Borer Treatments

Treatments, which will cost \$97.50-\$150 per application as of 2020 depending on tree size, typically provide protection from EAB for up to two years, and thus, must be re-applied biennially. Arbor Masters is using a product which utilizes the chemical Emamectin Benzoate. ⁵⁴

⁴⁶ "Big Bluestem: Plant Care & Growing Guide - The Spruce." 15 Oct. 2021, <https://www.thespruce.com/big-bluestem-plant-profile-4845878>. Accessed 23 Feb. 2023.

⁴⁷ "Big Bluestem – Facts, Identification, How to Grow - GrowIt BuildIT." <https://growitbuildit.com/big-bluestem-andropogon-gerardii/>. Accessed 27 Feb. 2023.

⁵⁰ "How to Grow and Care for Northern Sea Oats - The Spruce." 29 Apr. 2022, <https://www.thespruce.com/northern-sea-oats-growing-guide-5224490>. Accessed 23 Feb. 2023.

⁵¹ "Chasmanthium latifolium (Indian Wood Oats, Inland Sea Oats" <https://plants.ces.ncsu.edu/plants/chasmanthium-latifolium/>. Accessed 27 Feb. 2023.

⁵² "Chasmanthium latifolium (Indian Wood Oats, Inland Sea Oats" <https://plants.ces.ncsu.edu/plants/chasmanthium-latifolium/>. Accessed 23 Feb. 2023.

⁵³ "River Oats (Chasmanthium latifolium) - Missouri Wildflowers Nursery." https://mowildflowers-net.3dcartstores.com/River-Oats-Chasmanthium-latifolium_p_88.html. Accessed 23 Feb. 2023.

⁵⁴ "Ash Trees and the Emerald Ash Borer - Wildwood, MO." <https://www.cityofwildwood.com/627/Ash-Trees-and-the-Emerald-Ash-Borer>. Accessed 27 Feb. 2023.

Treatment timing is important where the effectiveness of the pesticide targets the emerald ash borer during their larval and adult stages. Imidacloprid soil treatments generally require four to six weeks for uptake and distribution of the insecticide within the tree. For central midwest should be administered between January - February before so the pollinators aren't affected by the pesticide. This needs to be administered from winter to spring time and before fall.⁵⁵

Emamectin Benzoate is the only recommended pesticide to use within this site because the trees are located near a large body of water. If imidacloprid or dinotefuran are used, it can severely impact the local aquatic/insect ecosystem. The administration of Emamectin Benzoate treatment should be done by a professional such as an arborist, and can be applied through injection to the trunk using specialized equipment.⁵⁶ This treatment is effective as long as the ash tree has not reduced its canopy by 30%, if the tree has been infected more than that, the chances of its survival rate reduces significantly. Treatments are probably best applied between spring through late June or early July. The prices of these injections range from \$10 per diameter inch on each tree, and it has to be repeated every 2-3 years.

Table 5: Emerald Ash Borer Pesticide & Cost Estimate

Emerald Ash Borer Pesticide	Cost Per Application x Duration
Emamectin Benzoate treatment by Arbor Masters	\$97.50-\$150 per application as of 2020 depending on tree size,

Equipment and Accessibility Needs

These recommendations should be adjointed with professional observation from a certified arborist, entomologist, and tree removal specialist. The tree removal cost estimates will depend on each individual tree as height, width, slope and proximity to powerlines changes the price.

⁵⁵ "Ash Trees and the Emerald Ash Borer - Wildwood, MO." <https://www.cityofwildwood.com/627/Ash-Trees-and-the-Emerald-Ash-Borer>. Accessed 27 Feb. 2023.

⁵⁶ "The Economics of Dying Ash Trees in Connecticut." 15 Jul. 2016, <https://ctpa.org/wp-content/uploads/The-Economics-of-Dying-Ash-Trees-in-Connecticut-RCowles-2.pdf>. Accessed 27 Feb. 2023.

Check Dams Overview

Building a sequence of a few check dams upstream between cross-sections O and N (refer to Fulton Floodplain Map), where the mean velocity of the floodway is 16.9 and 16.3 feet per second, respectively, will help to minimize the intensity of high flow rates along the vulnerable section of the levee. Check dams should be placed such that the toe of one check dam is at the same elevation as the next check dam downstream.⁵⁷ Trees infected with the emerald ash borer along Smith Branch can be cut down and placed sequentially along the branch to act as check dams, minimizing the costs needed for supplies. Placing tree cuttings perpendicular to the stream flow, ramped up the embankment, and ideally anchored behind live trees will stabilize the check dam to help retain branches over time and prevent bank erosion.^{58 59} It is important to monitor the condition of the cuttings as they decay or move downstream over time.⁶⁰

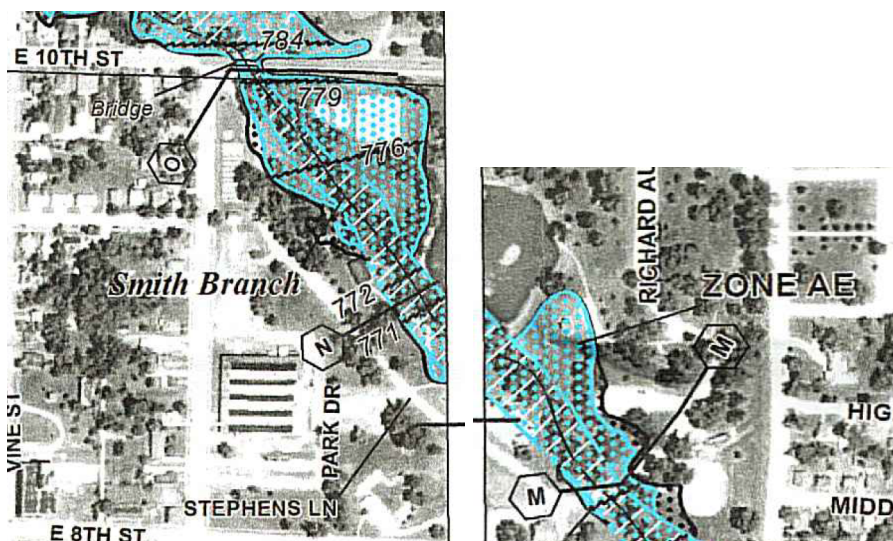


Figure 3: Floodplain Map of Veterans Park. The areas outlined in teal are the special flood hazard areas subject to inundation by the 1% annual chance flood

⁵⁷ "Check dams - LID SWM Planning and Design Guide." 16 Mar. 2022, https://wiki.sustainabletechnologies.ca/wiki/Check_dams. Accessed 27 Feb. 2023.

⁵⁸ "Engineered Large Wood Structures in Stream Restoration Projects" <https://www.mdpi.com/2073-4441/13/18/2520>. Accessed 23 Feb. 2023.

⁵⁹ "How To Stabilize Your Streambank: A Beginner's Guide - YouTube." 23 Feb. 2022, <https://www.youtube.com/watch?v=OWJsThItpk>. Accessed 23 Feb. 2023.

⁶⁰ "A Primer on the Wood Regime for Stream Management." <https://www.coloradosmp.org/wp-content/uploads/2023/01/A-Primer-on-the-Wood-Regime-for-Stream-Management.pdf>. Accessed 23 Feb. 2023.

Examples of Other Places That Implemented This Solution

Check dams have been effectively used by a number of state agencies in mitigating the erosion impacts of a stream on an embankment by decreasing the velocity of the stream. For a site in Minnesota, the implementation of check dams proved to have the primary effect of preventing channel bank erosion with a number of secondary benefits such as flow attenuation, sediment control, nutrient loading, etc.⁶¹ Further, the EPA recommends using check dams to prioritize runoff control where permanent channels lack vegetation and spacing them such that the toe of the upstream check dam is level with the crest of the subsequent downstream check dam.⁶²

Short-term vs. Long-term Stabilization Recommendations

The proposed solutions include a variety of both short term and long term solutions to provide quick relief to the eroding area while also prioritizing future plant growth and natural stabilization. The addition of a rock toe to the shoreline serves as a long term solution because bank reinforcement will reduce additional soil loss. This will preserve the new slope created through the regrading process and allow bank reinforcement through plant growth. The jute mats can be characterized as a short term solution due to their biodegradable nature. These mats are placed on top of the freshly graded soil to hold the soil in place while new vegetation is introduced. As the vegetation becomes more established the jute mats will degrade into the now stabilized soil. The labor intensive methods of creating a rock toe and regrading the slope will help to decrease erosion and mimic natural ecosystem processes in which soil deposition adds more soil to the region overtime instead of constantly losing new soil.

Table 6: Cost Analysis Summary of Short and Long Term Erosion Control Methods

Rehabilitative	Applicable Conditions and Function	Capital and
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⁶¹ "Sediment Control Practices - Minnesota Stormwater Manual." [https://stormwater.pca.state.mn.us/index.php?title=Sediment_control_practices_-_Check_dams_\(ditch_checks,_ditch_dikes\)&oldid=41613](https://stormwater.pca.state.mn.us/index.php?title=Sediment_control_practices_-_Check_dams_(ditch_checks,_ditch_dikes)&oldid=41613). Accessed 21 Feb. 2023.

⁶² "Check Dams - Environmental Protection Agency." <https://www.epa.gov/system/files/documents/2021-11/bmp-check-dams.pdf>. Accessed 21 Feb. 2023.

Method		Construction Costs
1) Regrading slope with soil	<ul style="list-style-type: none"> • Suitable where washout has exposed roots of existing vegetation. • Allows for reinforcement mats to be put down and new vegetation to grow. 	<ul style="list-style-type: none"> • Capital <ul style="list-style-type: none"> ○ ~146 cubic feet of Silt Loam⁶³ ○ ~75 tons of riprap rocks <ul style="list-style-type: none"> ■ ~\$1,540 • Construction <ul style="list-style-type: none"> ○ Excavator ~ \$330 for daily use ○ \$850 for the week (5 days)
2) Rock filled toe trench (riprap)	<ul style="list-style-type: none"> • For soils that remain stable during excavation with vertical slide slopes to depth below failure surface • Relatively low cost and quick installation • Allows for drainage of the slope 	
3) Jute/Coir Mats	<ul style="list-style-type: none"> • Suitable to protect against short term erosion of banks (3:1 - 2:1).⁶⁴ • Biodegrade in ~ 12-24 months. • Stabilizes soil to facilitate new vegetation growth. • Relatively easy and quick installation. 	<ul style="list-style-type: none"> • Capital <ul style="list-style-type: none"> ○ ~500 square feet of biodegradable mat ○ ~330 Steel Pins <ul style="list-style-type: none"> ■ ~\$400 • Installation <ul style="list-style-type: none"> ○ Tackling gun (rented) ~\$195/week ○ 10-Gauge Excavator/ Track Shovel ~\$100
4) Vegetation Restoration	<ul style="list-style-type: none"> • Plant after the jute matts have been stabilized to increase soil resilience created by the various root systems. • Allows for soil permeability. • Scattering seeds needs to be implemented before the first or last frost of the winter season. 	<p>Cost Per Quart Pot ~ River Oats: \$6.50 Big Bluestem: \$6.50</p>
5) Check Dams	<ul style="list-style-type: none"> • Installed temporarily at strategic cross-sections upstream from the 	<p><i>N/A</i></p>

⁶³ "Soil Calculator - Estimate Topsoil." https://www.inchcalculator.com/soil-calculator/?uc_length=50&uc_length_unit=foot&uc_width=5&uc_width_unit=foot&uc_depth=7&uc_depth_unit=inch&uc_calculator_type=length_width. Accessed 27 Feb. 2023.

⁶⁴ "Jute Matting | Erosion Control Options and Pricing." <https://www.erosioncontrol-products.com/jutematting.html>. Accessed 4 Feb. 2023.

	<p>project site to slow the velocity of flow at the project site.</p> <ul style="list-style-type: none"> ● Reduces erosion and gulying in branch, allowing sediment to settle. ● Can be built from rocks, logs, sandbags, etc. ● Easy installation and low cost ● Promotes sediment buildup which can help establish new vegetation. 	
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Appendix

Table A1. Supply companies and contact information

Jute Mats	Sandbaggy.com
	Zoro
Rip Rap	<i>Con-Agg Companies</i>
Mini-Excavator Rental	<i>Equipment Share- Columbia, MO</i>
	<i>Fabick Rentals- Columbia, MO</i>
Plants	<i>St. Louis Botanical Garden</i>
	<i>Angi's Tree Removal Service</i>
	<i>Missouri State Forest Nursery or George O White State Forest Nursery⁶⁵</i>

⁶⁵ "Missouri Department of Conservation | George O White State Forest"
<https://rngr.net/resources/directory/missouri-department-of-conservation--george-o.-white-state-forest-nursery/view>. Accessed 22 Feb. 2023.

	<i>Brandt's Lawncare and Tree Removal</i>
	<i>Advanced Tree Solutions</i>
	<i>Tree Wizard</i>

Fulton Floodplain Map

 Flood Plain 20230117.pdf

- **Companies Selling Jute Mats**

- Sandbaggy.com

<https://sandbaggy.com/products/jute-netting?variant=32793005817961>

- Zoro

https://www.zoro.com/mutual-industries-jute-mesh-blanket-225-length-x-4-width-17685-1-48/i/G2867284/?utm_source=google&utm_medium=surfaces&utm_campaign=shopping%20feed&utm_content=free%20google%20shopping%20clicks&gclid=Cj0KCOiA6fafBhC1ARIsAIJjL8koVsKdO2b2-G9bUmmlTYhFovUAOo2LD_XO5BStVa-vivuX_fiVrukaAtMtEALw_wcB

- **Where to buy rocks**

- <https://www.conagg-mo.com/contact/>

- 573-445-8393: Kim, Sales Representative, is familiar with the Fulton area and provided the cost estimates to purchase and transport the riprap.

- **Where to get machinery**

- Mini-Excavator Rental in Columbia, MO

https://www.catrentalstore.com/fabick-rents/en_US/products/earthmoving-equipment/family-mini-excavators.html

- Mini-Excavator Rental in Columbia, MO

https://rent-now.estrack.com/?&_ga=2.145895220.160150201.1676069705-994568671.1676069705#/home/rental/earthmoving/mini-excavators

- **Where to get soil**
- **How to calculate the quantity of soil needed**
 - https://www.inchcalculator.com/soil-calculator/?uc_length=50&uc_length_unit=foot&uc_width=5&uc_width_unit=foot&uc_depth=7&uc_depth_unit=inch&calculator_type=length_width
- **Where to get plants:**
 - St. Louis Botanical Gardens - <https://www.missouribotanicalgarden.org/>, Address: 4344 Shaw Blvd, St. Louis, MO 63110, Phone: (314) 577-5100
- **Grant options:**
 - Missouri Department of Conservation Tree Resource Improvement and Maintenance (TRIM) grants
- **People we consulted with or talked to, background with c2p2**
 - Micheal Burns
 - Sarah J. Phipps, State Survey Coordinator, Missouri Department of Agriculture, Plant Industries, Office: (573) 751-9334, agriculture.mo.gov
 - Robbie Doerhoff, Forest Entomologist, Robbie.Doerhoff@mdc.mo.gov
 - Collin Wamsley, State Entomologist, Missouri Department of Agriculture, Phone: (573) 751-5505, Collin.Wamsley@mda.mo.gov
 - Andrew Lanes, CCBER(Cheadle Center for Biodiversity & Ecological Restoration) Coordinator